GSM – LTE Migration: Deployment Issues for Operators in Developing Countries

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***Abstract*— The emergence of new applications such as mobile TV and increase in data usage motivated the 3rd Generation Partnership Project (3GPP) to introduce Long Term Evolution (LTE) in 2009 as the latest standard in the mobile network technology. GSM standard has been a remarkably successful 2G technology with large number of subscribers and installed base of infrastructures of above 86% market share. It is a circuit-switched system that has the ability to deliver 64 kbps to 120 Mbps of data rates and divides each 200 kHz channel into eight 25 kHz time-slots. It operates majorly either at 900MHz or 1800MHz frequency band and uses narrowband Time Division Multiple Access (TDMA) technique for transmitting signals. The main advantage of using GSM standard is the ability to allow customers to roam and switch carriers without having to replace their cell phones.**

LTE on the other hand is a 4G Network that provides higher data rate for subscribers at the same time reducing the cost per bit for service providers and much higher overall capacity to deliver more throughputs and reduced latency. It was designed to support only packet switched services to ensure minimal interference, reduce number of network elements by a simplified architecture and deployable in the spectrum bandwidth ranges from 1.25MHz–20MHz. Due to the variation in the frequency used in different regions, LTE is limited in its state of roaming with operators using different bands. In view of this, it is unlikely that LTE devices will work on other networks than its home network; except the users have phones with multi-band capabilities which can roam freely across the globe. Another challenge that LTE faces is Battery life of the devices. The large number of applications on LTE devices results in 5 -20% increase in power consumption compared to older phones.The use of a powerful battery with very long battery life after each charge is capable of extending talk time of the devices but ultimately increases device cost.

This paper discusses the issues affecting the network wide deployment of LTE in developing countries and proffers solution to some of the critical issues.

***Index Terms*—GSM, LTE, Frequency Reuse, OFDM**

Manuscript received March 9, 2015;
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I. INTRODUCTION

COMMUNICATION systems and services have undergone an extensive growth, since the first cellular and cordless telephone systems were introduced in the early 1980s. First generation cellular systems were based on analog technology and were designed to take care of narrow-band circuit switched voice services only. Second generation cellular systems were introduced in the early 1990s and they used digital modulation, and offered voice and better spectral efficiency [1].

Third generation wireless systems offered significantly higher bit rates and were designed to provide voice, data and multimedia services while the consistent increase in data usage and new applications such as online gaming brought about the Fourth generation systems which is capable of delivering higher transmission data rate, lower latency, better quality of service as well as improved spectral efficiency [2]. Despite the promising features of this technology there are still challenges with the cost and some technical specification as applied to deployments in developing countries.

II. GSM TECHNOLOGY

A. *Frequency Reuse*

Frequency reuse is a concept which allows the reuse of frequencies over diverse geographical area called cells; the cells are usually hexagonal in shape thus cells with the same number have the same set of frequencies.

Frequency reuse is based on the fact that radio waves get attenuated after certain distances such that signals fall below certain point and can no longer be used. Frequency reuse brings about improved spectrum efficiency and significant increase in user's capacity by serving millions of users with limited radio spectrum. It allows the frequency to be reused at different locations. Operators limit the cell size by minimizing the transmission from Base Transceiver Station (BTS) so that the frequencies can be reused in different cell.

The recurrence of frequencies results in cell clusters consisting of a group of seven adjacent cells. Therefore, users in adjacent cells do not use the same set of frequencies to avoid interference. As shown in fig. 1, cells with the same letter use the same set of frequencies called reuse cells, with a cluster size of N cells and k number of channels per cell.

ISBN: 978-988-19253-4-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

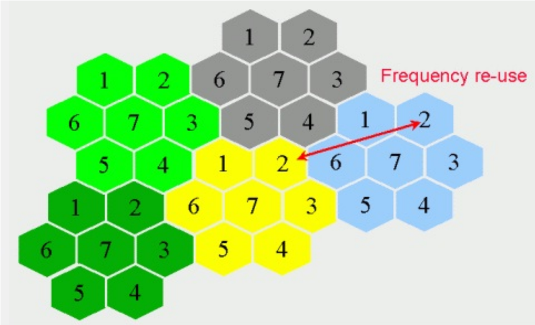

Fig. 1. Cells showing reuse factor of 1/7

Therefore, for a total number of channels available S = k*N, where N is the number of cells per cluster and k is the number of channel per cell.

If a cluster is replicated M times within a system, the total number of channel capacity C =M k*N=MS

The Reuse factor is a fraction of total available channels assigned to each cell within a cluster which is 1/N.

B. Time Division Multiple Access (TDMA)

Time division multiple access (TDMA) is a channel access method which allows several users to share the same frequency channel by dividing the signal into different time slots such that users transmit in a fast sequence, one after the other, each using his own time slot.i.e.it uses 200kHz per radio channel, and the channels are divided into eight 25kHz time-slots which will enable up to eight users to access each carrier. The figure below illustrates how up to eight users can share a 200-kHz channel in different time slots within a frame of 1248 bits.

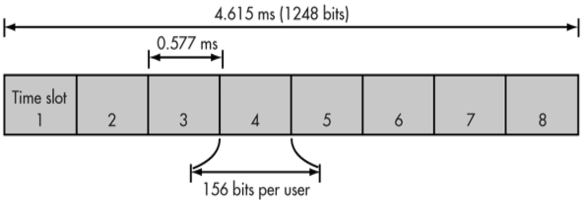

Fig. 2. TDMA time slot for 8users

Among the unique specifications of GSM are summarized in Table I: [3]

Key advantages of GSM include international roaming capabilities and security against fraud through an efficient user authentication. The handsets also enjoy low battery life with reduction in RF transmission power. Finally, its ability to encrypt information for privacy and security purposes and distinguish user and device identification are also great benefits of the GSM technology.

III. Long Term Evolution (LTE)

LTE is the evolution of mobile cellular communications technology towards an all IP technology.

It was designed to support only packet switched services to ensure minimal interference, reduce number of network elements by a simplified architecture, support real time application due to reduced latency, provide simple use and access with greater security and privacy as well as improve spectral efficiency [2].

TABLE I
Summary of GSM Unique Specification

Technical Specification	Characteristics
Multiple access technology	TDMA
Data rate	It has an ability to carry 64 kbps to 120 Mbps of data
Uplink and Downlink frequency band for GSM 900	It uses 890 - 915 MHz to send information from the Mobile Station to the Base Transceiver Station (uplink) and 935 - 960 MHz from the Base Transceiver Station to the Mobile Station (downlink).
Uplink and Downlink frequency band for GSM 1800	It uses 1710 – 178 5 MHz to send information from the Mobile Station to the Base Transceiver Station (uplink) and 1805 - 1880 MHz Base Transceiver Station to the Mobile Station (downlink)
Channel spacing	200 kHz
Modulation	Gaussian minimum shift keying (GMSK)
Number of user per frame	8
Frame period	4.615 ms

A. LTE Architecture

LTE network shown in fig. 3 is based on the Evolved Packet System (EPS) which comprises the User Equipment, Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC)

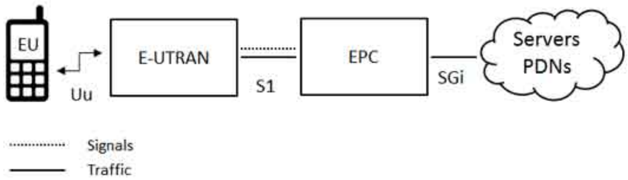

Fig. 3. LTE network architecture

B. Orthogonal Frequency Division Multiple (OFDM)

LTE uses Orthogonal Frequency Division Multiple (OFDM) in downlink transmission.

OFDM is a particular form of multicarrier modulation (MCM).The basic Principle of MCM is to divide a radio frequency channel into several narrowband parallel subcarriers and transmits data simultaneously on each subcarrier. OFDM is apt for high data rate systems that operate in multipath environments because of its robustness to delay spread.

Single Carrier Frequency Division Multiple Access (SC-FDMA) is used in uplink direction due to its better power to Average Power Ratio (PAPR) to maximize coverage area.

Table II below gives a summary of some unique specification of LTE:[4]

ISBN: 978-988-19253-4-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE II
SUMMARY OF LTE UNIQUE SPECIFICATION

Technical Specification	Characteristics
Peak Data Rate	To support 100Mb/s for its downlink transmission and 50Mb/s for uplink transmission
Control Plane Capacity	To sustain at least 200 users in each cell with at least 5MHz bandwidth in an active state
Control Plane Latency	To allow 100ms transition time from a camped state to an active state and below 50ms from an inactive state to an active state
User Plane Throughput	Average user throughput is 3-4times HSDPA release 6 in the downlink and 2-3times Enhanced Uplink release 6 in the uplink
User Plane Latency	To allow below 5ms transmission time for small IP packets in unload state
Inter-working and co-existence with 3GPP Radio Access Technology	Ability of LTE radio network to operate simultaneously with GSM &UMTS radio networks in a particular location with interruption time less than 300ms in cases of inter system handover
Mobility	To sustain network communication at speeds of up to 500km/h and improve performance for mobile speed between 15 and 120km/h
Data Type	All IP switched voice and data

LTE is part of the GSM evolutionary path for mobile broadband, following GPRS, EDGE, UMTS, HSPA and HSPA Evolution HSPA+. HSPA+ is a stepping-stone to LTE.

Due to the scalable bandwidth from 1.25MHz down to 20MHz, operators in developing countries will have to migrate their networks and users from GSM-EDGE-UMTS-HSPA and finally to LTE gradually over time, since it will require some changes in the architecture, technology, modulation schemes and other unseen technical challenges that might arise in the process of migration. However recent developments in LTE standards have made it is possible to migrate GSM to LTE directly without following this path [5].

IV. DEPLOYMENT CHALLENGES AND CONSIDERATIONS

Before operators in developing countries can start the deployment of LTE the following questions must be satisfactorily answered

1. Where to start from: urban, suburban or rural areas?
2. Which frequency band is ideal with bandwidth and coverage considerations in place?
3. How do we deal with the existing network- either 2G or 3G?
4. How should Interference issues be managed for network planning and optimization?
5. Should the focus be on Contiguous areas or hot spot roll out?

The answers to these questions will be a reliable guide to the following considerations in the deployment exercise:[6]

1. Existence of a seamless network connection

A seamlessly connected network increases user experience, retains investments, adds flexibility, and improves efficiency. It is obvious that LTE will provide users with effortless access to voice, data and multimedia services, but the achievement lies in the evolution of GSM/UMTS/HSPA and LTE networks where all the networks appear to the user as a single seamless network given an imperceptible roaming from one technology to another thus providing good coverage world over.

It also offers the necessary capacity needed to deliver the same kind of service to users at any given time thus allowing operators to offer the best quality of service in terms cost and resource management.

2. Optimization of the existing resources

The deployment of LTE could be carried out by taking advantage of existing network sites and installed ancillaries such that operators in developing countries can reuse the existing equipment which will overall reduce the cost of deploying a new network.

For instance, the radio access network is one of the most expensive parts of a wireless network and the cost of ancillaries and site acquisition can be as high as 10x the cost of the BTS.[6] Hence, re-using existing site grid enables capital expenditure (capex) savings. Also, operating expenses (opex) will offer reduced operational savings in respect to a single billing system in terms of personnel and training costs as well as considerable increase in network capacity.

3. Flexible Deployment

LTE can co-exist with GSM such that its scalable bandwidth gives operators the option to gradually refarm GSM spectrum for LTE services.GSM frequency bands are a significant part of the operators total frequency asset and best use of it will be good both in GSM and LTE.

GSM 900MHz has good coverage which results in reduced cost of deployment while some operators have GSM allocation in 1800MHz band which offers more bandwidth. With LTE scalable bandwidth between 1.4MHz to 20MHz, means LTE can be deployed both in the smaller and larger bandwidth to utilize the unused spectrum.

It is obvious from figure 4 that LTE deployment has taken place in most part of the developed countries while some developing countries-mostly in Africa, are still on the 3G networks. At the bottom of the technology ladder are some African countries like Niger, Chad, Mali and the likes still on the GSM networks without any pressing need to upgrade to faster technology in the immediate future.

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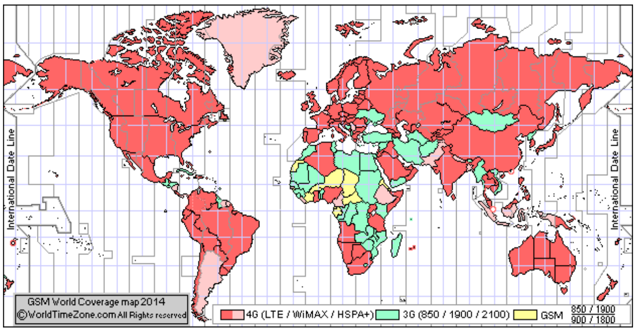

Fig. 4. GSM world coverage map [8]

V. Mitigating Strategies

Apart from obvious technological issues involved with this upgrade, the biggest challenge to the deployment of LTE in developing countries is the economics. And until the maturity of these markets is good enough to justify the investment, it might take a while for either partial or full roll out. The strategies that can be deployed to mitigate these issues must be built around addressing the following problems observed on the demand side:

1. Demand for data: the profile or consumption patterns of data must go beyond basic profiles of the use of the web for browsing, social networking and video streaming.

2. Affordability of Handsets: The entry price for LTE enabled handsets is more expensive than the ones for their GSM counterparts. Operators must work with handset manufacturers to address the chasm.

3. Network coverage: broadband adoption is slow on a national scale with focus on the cities at the detriment of sub urban and rural areas. This model must be reviewed with proper incentive from government to encourage investments in this area.

On the supply side, the focus of operators must be on how to develop premium pricing strategies, content bundling, and broadening connectivity to a wider range of devices -through multi-device tariffs. A combination of these creative marketing approaches will surely encourage greater investment and subsequent deployment of the technology in these areas.

For the technical issues, the following methods have been used by operators for successful upgrade to LTE [9].

1. Radio Resource Management: for the optimization of the EUTRAN by paying attention to the radio side of the network.

2. Efficient Management of Network Expansion: this involves the decision making process regarding capacity planning to be based on reliable information by foreseeing and monitoring future capacity expansion needs based on users' Key performance indicator(KPI).

3. Provision of Excellent Data Services: This is achieved by having a good understanding of the users' usage and behavior to adapt services to users' expectation, thus measuring the Quality of experience of each application and identifying challenges causing restrictions.

4. Interoperability between Multi-vendor Networks: The complex ecosystem between single EPC vendor and multiple EUTRAN vendors must be seamless.

VI. Conclusion

The compelling advantages of LTE which ranges from increase in overall data rate, multi-path handling capabilities, negligible cell interference, and overhead/cost controls to efficient frequency scheduling for greater flexibility are striving to convince two economically different worlds on the need for the adoption. However, this is being matched unequally with limitations in roaming due to frequency variation in different regions and high power consumption of devices as a result of multiple applications.

While the deployment is going on rapidly in developed countries, the developing counterparts are trying to balance economic realities with available resources to optimize the huge incentive this upgrade offers to the world technologically. This difference which we have seen to be economical can be resolved the moment service providers can monetize their services and the governments provide infrastructural incentives to encourage the massive financial outlay needed for full deployment of the technology.

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